

# **INSTRUCTIONAL AND TECHNOLOGICAL DESIGN OF E-LEARNING COURSES\***

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## **ABSTRACT**

E-learning course developers now have guidelines on how to develop the course, but there is not yet a method providing guidance for experts on how to design its educational contents. Neither is there a measure that can objectively assess whether the educational contents have been designed and structured efficiently according to the features of the learners being taught the contents. When an e-course comes to an end, the instructor checks, through the final assessment examination, each learner's achievement level, but cannot relate this achievement to the quality of the educational contents that define the course and are designed by the content expert. This chapter has two goals. First, it presents an instructional method that provides guidance for instructors as to how to design an e-course (as well as the lessons of which it is composed) and for content experts as to how to design the educational contents (the learning objects) for the e-course. Second, it describes a technological method that can be used to automatically create the e-course and evaluate the efficiency of the design of its educational contents. A tool, called the Adaptive Learning System, has been developed to implement the proposed technological model.

## INTRODUCTION

Learning is the acquisition of new mental schemata, knowledge, abilities, skills, etc., that can be used to solve problems potentially more successfully. Learning is also improving decision making through experience, which elevates *doing* as a basis for achieving an effective understanding of the knowledge [1], [2]. The learning process is optimised when it is assisted and personalised [3]. Computers can be used to personalise learning, they can design our learning according to our knowledge and needs, record progress made and pinpoint any mistaken thought process for correction [4]. With the development of the Internet, web technology-based computerised learning, known as e-learning [5], has increased drastically [6].

Initially, e-learning systems tended to focus exclusively on the management and measurement of training processes. They did not provide any means to support content production processes, e-content management or even maintenance [7]. Later, e-learning systems addressed the issue of educational e-content reusability, by means of which the same educational content can be used across different courses that are accessible via the Internet. One way of implementing this reusability is to provide editing tools for developers to create learning objects that are stored in a database. These learning objects can then be combined to create e-learning courses. Each course can be labelled with the correct level of Bloom's taxonomy for the cognitive domain it targets [8].

Nowadays, e-learning systems are able to generate adaptive e-learning content on demand, that is, produce a made-to-measure course depending on what a learner already knows. Some authors [9] propose an architecture consisting of extending the manifest XML file of each content package to include the information needed to define adaptation rules that determine how learning objects should be selected for different learner profiles. Other authors [10] provide frameworks for self-adaptive learning, for example, an adaptive course construction toolkit.

The e-learning system architecture is now based on learning objects or Sharable Content Objects (SCOs), as defined in the Sharable Content Object Reference Model (SCORM) [11] [12]. A SCO is a small learning unit, such that potential reuse across multiple learning objectives is feasible. Thanks to this potential, SCOs were able to be used as reusable adaptive learning materials [13], i.e. learning materials whose format is such that a learning management system can select different learning objects for different learners [12], [8].

The underlying problem is still that while SCO contents are designed by a content expert, used by the instructor to create e-lessons and the e-course, and learned by the learner, there is no method for assessing whether these contents, which have been used by different learners in different e-courses, are well designed for learning. Neither are there any methods that provide the content expert with guidance for designing these learning objects.

The chapter deals with these issues by describing:

- An instructional design method that allows the instructor to design an e-course tailored to the learning process and the content expert to design SCOs tailored to the learner.
- A technological design method for creating an e-course in which the instructional design of the learning objects can be evaluated in terms of e-content learning

## **THEORETICAL BACKGROUND: LEARNING OBJECTS AND LEARNING OBJECTIVES**

The concept of learning object refers to a generally small-sized, reusable instructional component, designed for distribution over the Internet for use in different learning management systems (LMS) and for access by many users. The IEEE Learning Technology Standards Committee (LTSC) [14] defines learning object as “any entity, digital or otherwise, that can be used, reused or referenced during computer-assisted learning”.

Learning objects can be combined to support individual instructional objectives to serve different contexts. An important characteristic of learning objects is that they should be self-contained. They go by several names in the learning field: educational objects, knowledge objects, training objects, RLO (Reusable Learning Object), SCO (Sharable Content Object). SCO, coined by SCORM from the concept of learning object given by IMS [15], is the most commonly accepted term for learning and reuse elements.

The structure of a SCO includes other content elements, called assets (electronic representations of media, text, images, sound, web pages, assessment objects or other data items that can be delivered to a web client [16]). So, a SCO represents a collection of one or more assets that, together, define a single, self-contained learning element.

A SCO is described by SCO meta-data that provide descriptive information about the content represented in the SCO. The purpose of meta-data (data about data) is to provide a common nomenclature for describing learning resources. Learning resources that are described by meta-data can be systematically searched and retrieved for use and reuse within a repository. SCORM has adopted the same set of meta-data elements described in the IMS Learning Resource Meta-data Information Model [17]. SCOs are designed by the *content expert* and stored in SCO repositories.

By way of an example, suppose an e-course is to be built to train a group of learners to “Navigate the Internet” and the content expert has created the following learning objects:

- **Browser Basics:** This contains knowledge of the basic use of a navigator.
- **Navigation Bar, Button Bar and Menu Bar:** These illustrate the use of a browser Navigation Bar, Button Bar and Menu Bar, respectively.
- **Configuration Settings:** This explains how to configure a browser.
- **Page Invocation:** This describes how to invoke web pages using a browser.
- **URL:** This illustrates the concept of URL (Uniform Resource Location), what it is used for and how to send information to a server through an URL.
- **Internet Navigation:** Based on page invocation and URL knowledge, this describes how to navigate, search the web, etc.

Each learning object includes a solved exercise, if applicable, and, in all cases, an assessment exercise that serves the purpose of evaluating whether the learner has learnt this learning object.

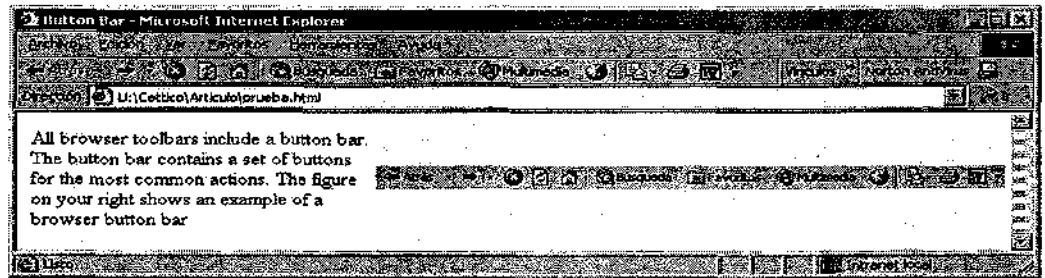


Figure 1. Button Bar interface on the screen of a learner.

Figure 1 illustrates the appearance (interface) of the SCO called Button Bar. This SCO describes the operation of the browser button bar on a learner screen. It shows that the Button Bar SCO is composed of two assets: a gif file containing the image of the button bar and an html file containing the text and format of the bar. This SCO would be part of an e-lesson of this e-course.

A learning objective is the specific knowledge that the learner has to acquire about a concept or skill. This knowledge generally includes several learning objects. The instructor designs the learning objectives using SCOs and stores them in a learning objectives repository.

The instructor plans an e-course by defining the learning process for a set of learning objectives that the learner has to achieve. The result (the e-course) is a set of e-lessons, each of which is a learning objective, composed of learning objects. Therefore, each learning objective will be defined by a set of interrelated SCOs that each deal with a very specific item of knowledge: educational content, tasks, solved exercises or evaluation exercises.

In the Internet Navigation example, the instructor has defined four learning objectives (e-lessons): The Toolbar, Configuration Settings, Page Invocation and Internet Navigation. The educational content learning objects used to define the Toolbar are: Browser Basics, Button Bar, Menu Bar and Navigation Bar. Configuration Settings contains one learning object of the same name, including the educational content that explains how to configure a browser. Page Invocation is composed of the URL and Page Invocation learning objects. Finally, Internet Navigation explains in one learning object of the same name how to navigate the Internet using all the above concepts. All e-lessons have some solved and evaluation exercises, which group all the exercises defined by the content expert for each learning object.

The roles involved in the process of developing, deploying and running an e-course on the e-learning platform are:

- Content expert: the content expert is responsible for developing and storing the SCOs (educational content and exercises) in the learning objects repository.
- Master instructor: the master instructor groups SCOs to form learning objectives that are stored in the objectives repository. A *learning objective is equivalent to an e-lesson*. Additionally, the master instructor groups learning objectives to form an e-course.
- Instructor: The instructor defines the learner-tailored learning route, follows up the e-course for each learner taking the course, runs the final evaluation examination and

analyses any deviations in terms of the time taken to learn the SCOs and the results achieved by the learner in the exercises.

- **Learner:** the person who takes an e-course tailored to his or her earlier knowledge, based on the e-course designed by the master instructor.

## INSTRUCTIONAL DESIGN OF AN E-COURSE

An e-course (Figure 2) is composed of a set of learning objectives that make up e-lessons. An e-lesson is then a lesson implemented by means of learning objects and deployed in a learning management system (LMS).

As shown in Table 1, an e-course is composed of a table of contents, an introduction, some objectives, a conceptual content schema, from 3 to 6 lessons and some conclusions [18].

As discussed in section 5, the table of contents, the objectives and the conceptual content schema are automatically generated by the e-learning platform (LMS) from the learning objects of the e-lessons making up the e-course. When the master instructor groups the e-lessons to form an e-course, the system asks for the introduction and conclusions of the e-course to be written. Later, the estimated learning times for the introduction and conclusions sections are set at five minutes. All the estimated learning times for an e-course are shown in Table 1 and have been calculated from several years of experience in teaching e-learning courses to train information and communications technologies specialists [19].

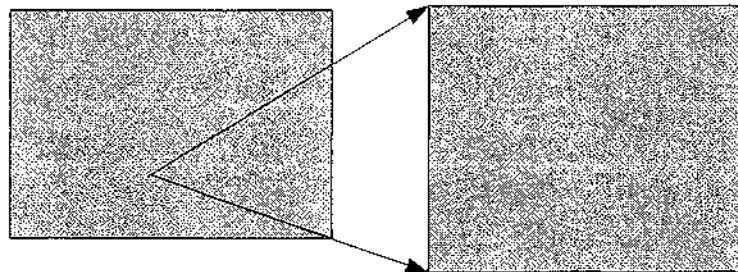


Figure 2. Structure of an e-course.

Table 1. Items making up an e-course

E-course items	Quantity	Estimated learning time	Implementation
1. Table of contents	1	<=5 min automatic	LMS
2. Introduction	1	5 min.	LMS
3. Objectives	1	<=5 min. automatic	LMS
4. Conceptual content schema	1	5 min. automatic	LMS
5. Lessons	3-6	<= 90 min. each	E-Lessons
6. Conclusions	1	5 min.	LMS

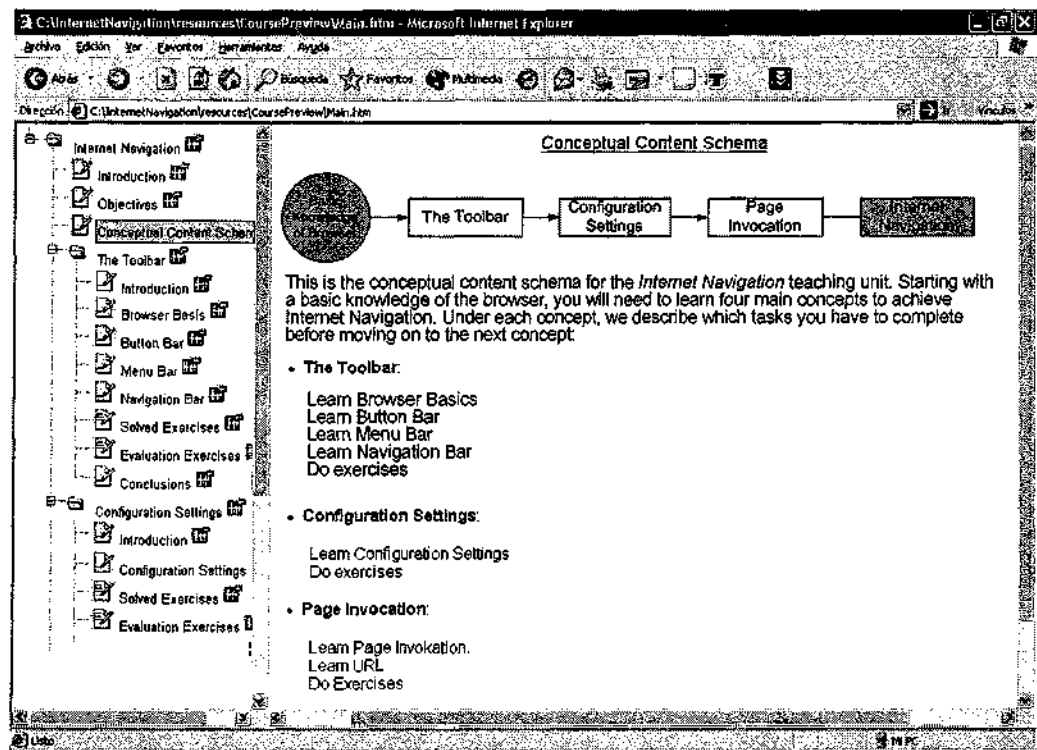


Figure 3. Conceptual Content Schema for Internet Navigation E-Course.

The left-hand side of Figure 3 shows the Internet Navigation e-course table of contents and the right hand side the e-course's Conceptual Content Schema.

This e-course is composed of an introduction, objectives, conceptual content schema, four e-lessons: the toolbar, configuration settings, page invocation and Internet navigation and conclusions.

1. The *table of contents* is generated automatically by the Adaptive Learning System that implements the technological model described in section 5. The table of contents is the student's first contact with the e-course. It is composed of an index, and its content answers the reader's question concerning *what he or she is going to learn*, which implies curiosity of some sort and expectations that may or may not be positive. Therefore, it is essential for learners to analyse this index.

As the Adaptive Learning System builds the table of contents on the basis of the information contained in the SCO metadata and e-lessons of which the e-course is composed, the master instructor is responsible for assuring what SCOs are chosen and grouped as learning objectives so as to assure that the table of contents meets the following instructional requirements:

- The structure of the table of contents should follow a logical thread, starting from the more general and moving on to more detailed and specific knowledge, covering all the learning objectives proposed for the e-course and expected by the student. This structure implies that the contents should be described in order of increasing difficulty to assure gradual learning.

- There should be no more than three hierarchy levels in the index. These hierarchy levels match the e-lessons and the sections of which they are composed.
  - The titles should be short and descriptive enough for the learner to know what information the section contains. Generally, the titles of the table of contents should be suggestive and dynamic, using a direct language that, albeit formal, attracts the interest of anyone who reads it.
2. The *Introduction* provides an overview of the course, that is, it briefly describes the contents that are to be dealt with. The introduction puts the lessons, which are the learning objectives, into context.

Its main purpose is to explain to the learner what he or she is going to learn and motivate him or her to do so, describing what benefits and accomplishments he or she will gain from the course. This will be meaningful if he or she feels it is going to be useful to him or her and it matches his or her field of interest.

The introduction should attach importance to the essentials and create positive but realistic expectations. In this respect, it is important that it should refer to each of the lessons and their interrelationship, as well as identifying any individual concepts mentioned within the knowledge graph making up the e-course or relating them to less advanced knowledge that the student is assumed to have. On the other hand, the introduction must not be too long (approximately one screen) and should take about five minutes to read.

3. *Objectives*: Like the table of contents, the objectives of an e-course are automatically generated by the Adapted Learning System from the metadata contained within the learning objectives. Therefore, when the master instructor groups SCOs to form a learning objective, it must take into account the following points:
- The objectives should be described using short sentences and very direct messages that inform the learner about what their goal is and what the learner will achieve so that he or she knows what to focus on. Each objective of the e-course matches one of the lessons of which it is composed.
  - The learning objectives should be tested by means of practical exercises in the lessons to evaluate whether or not they have been achieved and, therefore, whether the e-course needs to be modified.
4. The *Conceptual Content Schema* is a diagram of the objectives list covered by the e-course. This list is represented as a one-way acyclical directed graph that organises the concepts to be learned linearly. The concepts are located in the graph nodes and the directed lines linking the nodes indicate the learning sequence. In this manner, the learner can visually check what the course contents are and how they are related.

The right-hand side of Figure 3 shows the conceptual content schema generated for the Internet Navigation e-course.

5. *Lessons*: As specified in [19], each e-course must be composed of from 3 to 6 lessons. A lesson matches a learning objective and is implemented by means of learning objects deployed in a LMS, when they are termed e-lessons. Lessons are the backbone of e-courses, as they are what provide the educational content that the learner is to learn. Their instructional design is described in section 3.A.

6. The *Conclusions* help the learner to revise the information and improve memorisation at the end of an e-course. Therefore, they should be brief (about half a screen) and include the main ideas and concepts addressed.

## Lessons

When developing a training programme, the lesson structure should assure that the contents of its different learning objects are put together coherently. This structure provides a framework that covers all the needs of the instructional learning methods. The maximum learning time for each e-lesson should be 90 minutes.

A lesson is composed of the seven sections shown in Table 2.

The 1. *Table of contents*, 2. *Introduction*, and 7. *Conclusions* sections fulfil the same function as their respective sections for the full e-course, although they are more specific as they refer to the lesson in particular. The table of contents is automatically generated by the system from the content included in the learning objects making up the e-lesson, whereas the system asks for the Introduction and the Conclusions to be written when the master instructor groups the set of learning objects that are to make up the e-lesson.

3. *Educational content* teaches the information associated with the steps or indications required to execute the task. This knowledge is basically divided into facts, concepts and processes. The *facts* describe unique and specific information. *Concepts* show information explaining the objects, symbols, ideas or events that are named by means of a word or term, share a common feature or differ on features of little significance. *Processes* describe how the procedures in the teaching domain operate. There are two process types: business processes, which describe how organisations operate, and technical processes, which describe how equipment and machines work. In the example shown in Figure 3, the lesson titled "The Toolbar" contains SCOs that include educational content, specifically technical processes: Browser Basis, Button Bar, Menu Bar and Navigation Bar.

4. *Tasks* teach skills to be learned. They are based on procedures and guides derived from principles. A *procedure* is a sequence of steps followed by a person to do a task or make a decision. It lists the task instructions for completing the procedure in question. For a given situation, the actions within a procedure must always be carried out in the same way. *Principles* are distinguished from procedures by the fact that the steps that they teach can vary over time, for which reason they illustrate a series of steps giving guidance in different situations. In principle, a cause-effect relationship is established with a predictable result, and guidelines must be provided for best practices based on observation and experience. Again, the lesson titled "Configuration Settings" in the example shown in Figure 3 contains one SCO of the same name that matches a procedure.

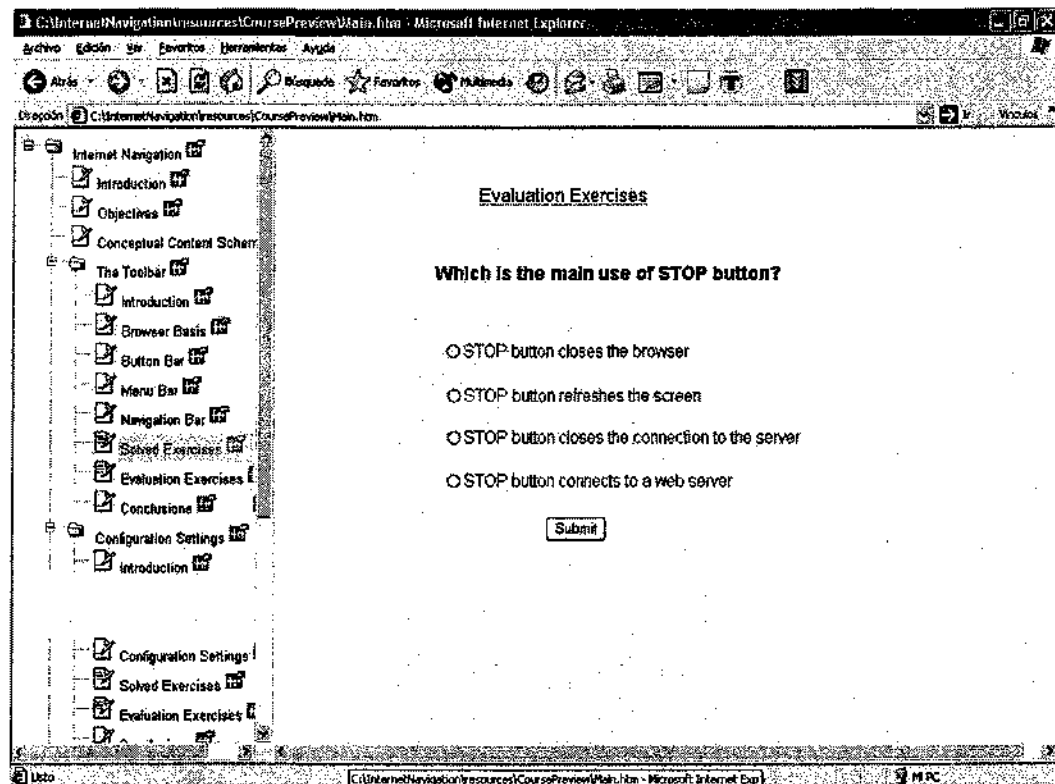
5. *Solved exercises* help learners to observe everything that has been described in the contents in practice and make it clear and visible how to actually apply the described contents. Exercises like this can reinforce learning. Exercises are stated as if they were problems for the learner to solve and they are solved stepwise. The solution should be set out using well-defined steps, which will illustrate and clarify the main thread leading to correct problem solving. For this purpose, the problem-solving process needs to be clearly explained, stressing the problem-solving steps.



**Table 2. Sections making up a lesson**

Section	Amount	Source	Estimated learning time
1. Table of contents	1	LMS	<= 3 min. automatic
2. Introduction	1	LMS	5 min.
3. Educational content	Any	SCO Repository	1 - 15 min. for each SCO
4. Tasks	Any	SCO Repository	7 - 10 min.
5. Solved exercises	1	LMS from SCO repository	5 - 10 min.
6. Eval. exercises	1	LMS from SCO repository	5 - 10 min.
7. Conclusions	1	LMS	5 min.

6. *Evaluation exercises* are essential, because they help the learner to put the theoretical content taught into practice. There should be an evaluation exercise at the end of each e-lesson, because they are easier to solve when the information is fresh, which is more motivating. Additionally, it is a way of revising this information, providing a means for the learner to do a quick self-assessment and check whether he or she is understanding the conveyed information. For this last reason, the solution must be given just after the exercise is completed at the end of each lesson. The evaluation exercise must be brief and to the point, and have a clear objective. Additionally, the exercise should be entertaining and dynamic.



**Figure 4. Specimen Evaluation Exercise for Internet Navigation E-Course.**

Exercises like these reinforce understanding and learning immediately after the information has been taught, help the learner to generalise what he or she has learned to the situations in which it has to be applied and enliven the learning process, as they offer a break from theory, that is, a change in a continuum.

Evaluation exercises can be formulated by means of short questions and several possible responses, from which the learner must choose the right answer. Another option is to describe an exercise or case study for the learner to explain. Figure 4 shows a possible multiple-choice evaluation exercise for the button bar learning object of the Internet Navigation e-course that is being used as an example.

The system automatically gets these exercises from the evaluation exercises designed by the content expert for each learning object. Educational content, tasks, solved exercises and evaluation exercises are referred to as the content sections of an e-lesson.

## INSTRUCTIONAL DESIGN OF LEARNING OBJECT CONTENT

The learning objects that implement the educational content and tasks of an e-lesson are mainly facts, concepts, processes, procedures and principles. Generally, they all include an *Introduction* asset that establishes the purpose of the learning object and provides the learner with guidance about what he or she can expect to learn. Additionally, when the content expert designs a learning object with educational content, he or she incorporates specific solved and evaluation exercises for that object. The instructional design of each one of these learning objects is described in the following:

- a) *Facts*: Each asset making up a learning object for teaching a fact may contain an illustration, an animation, a list or a table
  - *Illustration*. An illustration improves the description of the fact being taught. It is normally preceded by a descriptive sentence, followed by a table that indicates its key parts. Within the illustration, the regions of greater interest may be labelled by means of short sentences and arrows.
  - *Animation*. When the facts to be described are complex, an animation may be used to provide a better visual understanding. The animation may evolve automatically, although, for processes that have a lot of stages, it should be learner induced, for example, by mouse clicks.
  - *List*. Lists are good for describing categories and can include labels that describe the relationships of inclusion between these categories.
  - *Table*. Tables are good for giving brief descriptions. Headings should be used to describe the contents of the columns and/or rows.
- b) *Concept*: The assets that implement concepts usually include a definition, a fact, an example, a counterexample or an analogy.
  - *Definition*. This asset contains the description of the concept. The definition can be expressed textually or by means of a graph or illustration. In any case, it must be clear, concise and very much focused on its goal. Bullets can be used if the features of what is being defined need to be listed, for example.

- *Fact*. A concept can reference other learning objects that contain facts required to learn a concept.
  - *Example*. Generally, two or more assets are included that all contain examples in order of increasing complexity, using graphs if necessary.
  - *Counterexample*. Although they have the same instructional features as the example, these assets are used to illustrate examples that can easily be mixed up with the concept that is being taught in the learning object.
  - *Analogy*. Analogy is an instructionally speaking very powerful asset, because its inclusion allows the learner to relate the concept to his or her own experience.
- c) *Process*: Each asset making up a learning object for learning a process usually contains a table, a diagram or an animation.
- *Process table*. This asset describes the stages of the process, also indicating who performs each activity and when.
  - *Diagram*. Its inclusion in the process illustrates the stages of the processes graphically, which improves learning as illustrations are easier to remember than text.
  - *Animation*: In more complex processes, animations can be included that depict the different stages and the order in which they are performed within a process for the learner.
- d) *Procedure*: The assets that form a learning object of this type usually contain a fact, a procedure table, a decision table, a demonstration or a table combining any of the above.
- *Fact*. A learning object that teaches a procedure can refer to one or more learning objects that teach facts when a procedure needs to be explained.
  - *Procedure table*. The procedure needs to have an asset that is either a procedure table or a decision table. This table is introduced by means of a descriptive sentence and has at least two columns labelled with the words “steps” and “actions”. Each step starts with an action verb and is confined to a single action.
  - *Decision table*. Like the procedure table, the decision table is preceded by an introductory sentence, although, in this case, the headings of the columns are labelled with the words “if”, which contains the condition, and “then” with the action.
  - *Demonstration*. Used to illustrate the procedure when necessary. These assets usually contain a viewlet.
- e) *Principles*: Each asset making up a learning object that teaches a principle contains either a good practices guide, an example or a counterexample.
- *Guideline*. A guideline includes specific and full instructions about the principle, using measurable action verbs.
  - *Example*. It is usual to include at least one or two assets each containing an example. These examples are used to illustrate how to perform the steps included in the guideline.
  - *Counterexample*. It is a complementary asset that distinguishes between cases that, although similar, are not part of the principle.

## TECHNOLOGICAL DESIGN OF AN E-COURSE AND EVALUATION OF SCO INSTRUCTIONAL DESIGN

When a content expert now designs a learning object, he or she does not know whether learners have understood the object as efficiently as expected during its design. In other words, the content expert has no idea whether the learning object has been well designed bearing in mind the features of the target learners.

Additionally, the estimated time for learning an e-course depends on the estimated time for learning each of its educational objectives (e-lessons) and, therefore, the estimated learning time for each learning object. The master instructor now estimates this time heuristically without the content expert's involvement.

It is important for the master instructor to have an external expert's measure of the time it takes to learn each SCO. This is of assistance for properly scheduling the course and also for the content expert to find out whether his or her learning objects have been efficiently designed for learning.

To solve this problem, a series of mechanisms have been included in our on-demand e-courses construction technological model [13] that can evaluate the instructional design of the learning objects. For this purpose, each SCO includes four fields that specify: the time estimated by the content expert in which a learner can learn the learning object in question (*elt* - estimated learning time), the number of learners who have studied and passed the knowledge of this learning object (*pln* - passed learners number), the mean time spent on learning (*mlt* - mean learning time), and the standard deviation of the SCO mean learning time (*scoσ*). These values are used to schedule the e-course and to evaluate the SCO instructional design.

In the following, the technological design process of an e-course is described together with the evaluation of the instructional design of SCOs. Briefly, an e-course is designed from the SCOs that fulfil a set of learning objectives. The e-course is automatically tailored to the learner based on his or her initial knowledge. A tool, called Adaptive Learning System (ALS), has been built to implement this model. This tool provides four main toolkits: the Learning Objects Toolkit, which generates and manages the SCO Repository learning objects; the Learning Objectives Toolkit, which generates the Learning Objectives Repository; the E-Course Objectives Toolkit, which selects a set of learning objectives from the repository to build an e-course; and the Adaptive Learner Interface, which provides a graphical user interface for each learner to interact with the SCO questionnaires, whose contents are analysed to tailor the e-course to each learner. To be able to offer a course tailored to each individual learner, apart from the ALS, there also needs to be a SCORM-compatible authoring tool to develop the SCOs stored in the SCO repository and an e-learning platform to run the courses.



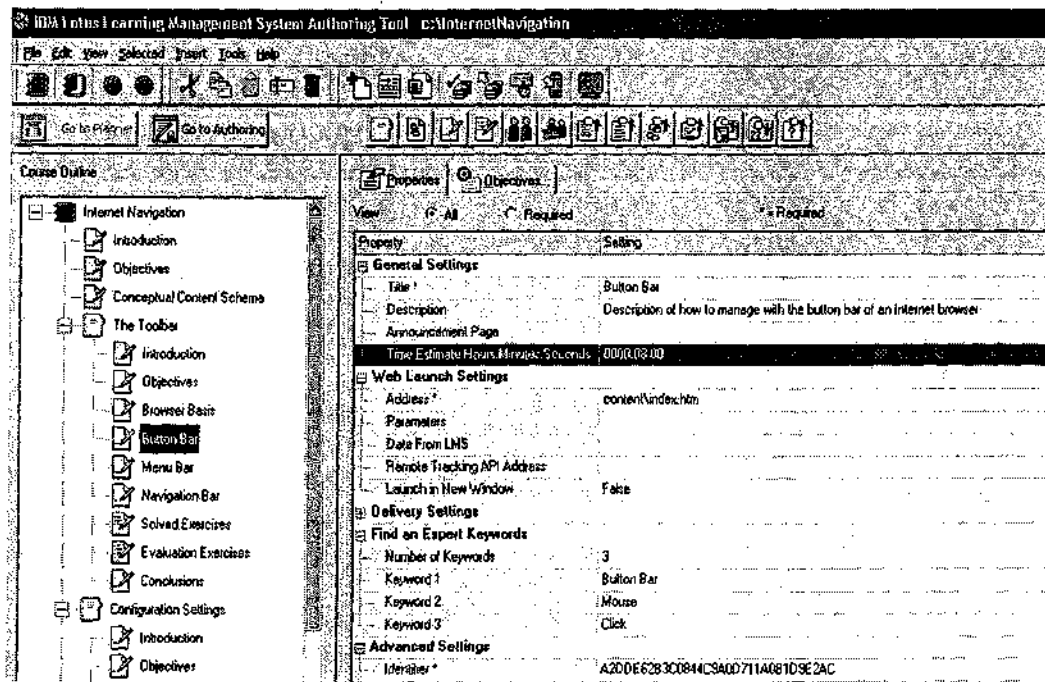


Figure 6. elt entry in the Button Bar SCO creation process.

For a given subject, the Learning Objects Toolkit displays its Dependencies Graph, based on the dependencies between the SCOs in the repository. From this graph, the content expert can detect inconsistencies between the relations defined between the learning objects of the subject in question. This activity is independent of e-course configuration and is carried out when new SCOs about a given subject are added to the repository.

## Learning Objectives Creation

The master instructor uses the Learning Objectives Toolkit to create learning objectives. To do this, the master instructor selects the Dependencies Graph subgraphs and labels them as specific learning objectives. Each objective, which is composed of one or more SCOs, defines an e-lesson. The system automatically defines the structure and contents of each e-lesson, and the master instructor adds the content of the Introduction and Conclusions sections. Then, the system calculates and displays the total lesson estimated learning time (*lessonelt*), which is the sum of the *elt* values for each SCO and other sections making up this e-lesson. Figure 7 shows a screenshot of the Learning Objectives Toolkit used by the master instructor asking him or her to write the Introduction for the lesson titled "The Toolbar" within the Internet Navigation example.

These e-lessons (learning objectives) are stored in the Objectives Repository. Later, the instructor can create or modify these learning objectives at any time from the information in the SCO Repository. Learning objectives are usually defined before the e-course objectives.



values allow the master instructor to schedule the e-course learning time, removing or extending any objective as necessary.

### ***Learner Knowledge Elicitation***

Using the Adaptive Learner Interface, the system elicits what knowledge in the E-Course Knowledge Graph the learner has about the SCOs that he or she claims to know. As a result, it produces the Learner Knowledge Graph, which will be a subset of the E-Course Knowledge Graph, if the learner really does know some of the SCOs.

### ***Learner Objectives Definition***

The instructor uses ALS to inspect the Learner Knowledge Graph and remove inconsistencies. For example, a learner may know one SCO, but not another that is a prerequisite for the SCO he or she knows. From this inspected graph and the E-Course Objectives List, the system outputs: the Learner Objectives List, which shows the lessons included in the e-course for a given learner, and the Learner Road Map. The learner road map is the set of Hamiltonian paths that go from the start state to the goal state of the Learner Knowledge Graph: a connected, directed cyclical graph, whose nodes represent the learning objects.

### ***Learner Learning Route Definition***

The instructor uses the Learner Road Map and the ALS to define the learner's Learning Route for these learning contents, which is built by selecting what is in the instructor's opinion the best of all possible Hamiltonian paths for reaching the target knowledge state set out in the road map.

## **E-Course Development**

This process depends on the authoring tool used to develop the e-course. The system inputs the learner learning route and the tool builds the route into the LMS platform. It outputs the different instructional units and e-lessons. This process outputs the Self-Paced Learning Process applicable to a learning tree containing the structure and contents of each e-lesson.

## **E-Course Execution**

This activity involves the learner doing the e-lessons: learning the educational content and doing the solved and evaluation exercises. It provides information on the problems encountered and the knowledge acquired. Information output during execution is gathered and stored in the learner log within the e-learning platform, and the results are analysed against the learning objectives. The log can be used for monitoring purposes to determine successes and ascertain the learning product quality.



ALN Adaptive Learning System - Learner Log						
Course Learner Log						
Section	Start Date	Number of View	Time Estimated (min)	Time Elapsed (min)	Grade Out of 10	Status
E-Lesson: Toolbar	14/07/04	21	42 min	40 min		Not Passed
Table of contents	14/07/04	1	1 min	1 min	—	Finished
Introduction	14/07/04	1	2 min	2 min	—	Finished
Browser Basics	15/07/04	5	5 min	7 min	6	Finished
Button Bar	20/07/04	4	6 min	11 min	4	Not Passed
Menu Bar	23/07/04	3	7 min	9 min	3	Not Passed
Navigation Bar	27/07/04	4	8 min	6 min	7	Finished
Solved exercises	28/07/04	1	4 min	3 min		Finished
Evaluation exercises	29/07/04	2	5 min	7 min		Finished
Conclusions	30/07/04	1	2 min	2 min		Finished
E-Lesson: Conf. Set.			26 min			
Table of contents	02/08/04	—	1 min	1 min		Showing
Introduction	02/08/04	1	2 min	2 min		Finished
Configuration Settings	04/08/04	2	10 min	6 min		Learning
Solved exercises			5 min			Not Started
Evaluation exercises			6 min			Not Started
Conclusions			2 min			Not Started
E-Lesson: Page Inv.			33 min			Not Started
Table of contents			1 min			Not Started
Introduction			2 min			Not Started
Page invocation			7 min			Not Started
URL			9 min			Not Started
Solved exercises			5 min			Not Started
Evaluation exercises			7 min			Not Started
Conclusions			2 min			Not Started
E-Lesson: Int. Nav.			26 min			Not Started
Table of contents			1 min			Not Started
Introduction			2 min			Not Started
Internet Navigation			10 min			Not Started
Solved exercises			3 min			Not Started
Evaluation exercises			8 min			Not Started
Conclusions			2 min			Not Started
<b>TOTAL</b>		<b>24</b>	<b>2h 07 min</b>	<b>0h 59 min</b>	<b>Mean: 5.5</b>	

Figure 8. Learner log.

Table 3 shows, for the learning objects included within the Internet Navigation e-course, an example of the log of a learner who is taking the e-course. This learner started the course on 14 July, has visited the site on a total of 24 occasions, studied for a total of 59 minutes, completed the first e-lesson, not passing two of the learning objects and is now working on Configuration Settings within the second e-lesson.

The e-course learning time estimated by the content expert and master instructor was 2 hours and 7 minutes.

## E-Course Revision

This serves to refine the learning process by analysing the results of the e-course execution. The e-learning platform analyses the Learner Log and the Learner Learning Route, and modifies, if appropriate, the learner learning process, going on to execute process 4.

As illustrated in Figure 8, the learner received a good grade for Browser Basics learning. Then, he got two poor grades and, again, another good grade. This can occur when the route selected in the road map for reaching the target knowledge state is not optimum. The self-adapting learning system detects such situations and dynamically modifies the implementation of the course by jumping to step 4. This gives learners a different view of the contents to be learned to assure that they get good grades in all the sections of which the course is composed.

Every time a learner finishes an e-course, the learning platform updates the e-course log (Figure 9), which contains information on the number of learners who have passed each of the e-course items (*pln*), the estimated learning time (*elt*), the mean learning time taken (*mlt*) to learn them and the standard deviation with respect to the mean time taken (*scoσ*). This value refers to SCOs only. The *scoσ* value of the table of contents, introduction, objectives and conclusions are not collected, because, as they are not SCOs, their design is not evaluated. Although the results of calculating the *mlt* and *scoσ* values are real numbers, Table 4 shows the closest integer value to each one to ease SCO evaluation. Having calculated these values, they are added to the SCOs in the learning objects repository metadata.

e-Course Log				
Section	passed learners (pln)	estimated learning time (elt)	mean learning time (mlt)	standard deviation
<b>E-Lesson: Toolbar</b>	<b>123</b>	<b>42 min</b>	<b>45 min</b>	<b>5</b>
Table of contents	125	1 min.	1 min.	-
Introduction	125	2 min.	2 min.	-
Browser Basis	125	5 min.	6 min.	1
Button Bar	124	8 min.	11 min.	1
Menu Bar	124	7 min.	7 min.	1
Navigation Bar	123	8 min.	7 min.	1
Solved exercises	123	4 min.	4 min.	0
Evaluation exercises	123	5 min.	5 min.	1
Conclusions	123	2 min.	2 min.	-
<b>E-Lesson: Conf. Sett.</b>	<b>120</b>	<b>26 min</b>	<b>24 min</b>	<b>4</b>
Table of contents	123	1 min.	1 min.	-
Introduction	123	2 min.	2 min.	-
Configuration Settings	120	10 min.	9 min.	2
Solved Exercises	120	5 min.	4 min.	1
Evaluation exercises	120	6 min.	6 min.	1
Conclusions	120	2 min.	2 min.	-
<b>E-Lesson: Page Inv.</b>	<b>119</b>	<b>33 min</b>	<b>29 min</b>	<b>3</b>
Table of contents	120	1 min.	1 min.	-
Introduction	120	2 min.	2 min.	-
Page Invocation	120	7 min.	4 min.	1
URL	119	9 min.	9 min.	1
Solved exercises	119	5 min.	5 min.	1
Evaluation exercises	118	7 min.	6 min.	1
Conclusions	118	2 min.	2 min.	-
<b>E-Lesson: Int. Nav.</b>	<b>117</b>	<b>26 min</b>	<b>25 min</b>	<b>3</b>
Table of contents	118	1 min.	1 min.	-
Introduction	118	2 min.	2 min.	-
Internet Navigation	118	10 min.	8 min.	2
Solved exercises	117	3 min.	3 min.	0
Evaluation exercises	117	8 min.	9 min.	2
Conclusions	117	2 min.	2 min.	-
<b>TOTAL</b>		<b>2 h. 07 min.</b>	<b>2 h. 03 min.</b>	<b>7</b>

Figure 9. Internet navigation e-course log.

The statistical formula that calculates the  $sco\sigma$  value is as follows (1) [20]:

$$sco\sigma = \sqrt{\frac{\sum_{i=1}^{pln} (t_i - mlt)^2}{pln}} \quad (1)$$

where  $t_i$  is the time it takes the  $i^{th}$  learner to pass any SCO.

This formula needs all the learning time values of all the learners who have managed to pass each SCO to be available and recalculates the  $sco\sigma$  value every time a learner passes a SCO. Apart from being computationally very costly, it takes up a lot of memory space to store, for each SCO, all the  $t_i$  of each learner who has passed this SCO. Therefore, West's algorithm, an improved version of Hanson's Variance Estimation [21], was chosen to calculate the  $sco\sigma$  [22]. This algorithm can update the standard deviation when an additional data value is added to the sample. This is calculated from the new value entered in the sample and the earlier values (without taking into account the new value of the sample) of the mean ( $mlt$ ) and standard deviation ( $sco\sigma$ ).

For each e-lesson item, the variable for the time it takes a learner to study a SCO ( $t_{sco}$ ) was assumed to be normally distributed, and the mean ( $mlt$ ) and standard deviation ( $sco\sigma$ ) are calculated from the learning time values collected from each learner. The analytical expression of the density function of the variable  $t_{sco}$  is, therefore, (2) [20]:

$$f(t_{sco}) = \frac{1}{sco\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{t_{sco}-mlt}{sco\sigma}\right)^2} \quad (2)$$

Figure 10 illustrates the density function (2) for the particular case of the Button Bar SCO. In this case, and according to Table 4,  $mlt = 11$  minutes and  $sco\sigma = 1$ .

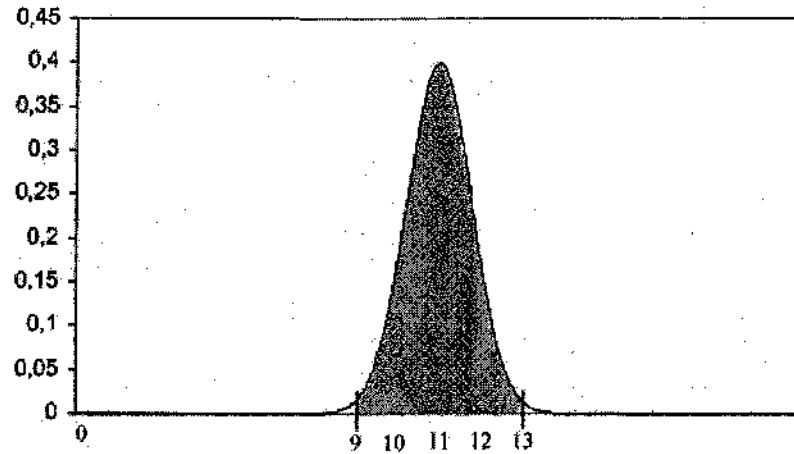


Figure 10. Button Bar learning time density function.

The density function area within the interval  $[t_{sco1}, t_{sco2}]$  represents the likelihood of a learner learning one particular SCO of an e-lesson in a time covered by the interval. So, for example, the probability of it taking a learner more than 11 minutes to study the Button Bar is 0.5, which is half the total area of its density function.

It holds that the density function area of any normal distribution around the mean with a radius twice the standard deviation is 0.95 [20]. Mapping this result to the case of the variable  $t_{sco}$ , there is a 0.95 probability that the learning time is within the interval  $[mlt-2\cdot sco\sigma, mlt+2\cdot sco\sigma]$  when the number of learners that have satisfactorily learned a SCO is high (a high value of  $pln$ ). In the particular case of the Button Bar example, where  $pln = 124$ ,  $mlt = 11$  minutes and  $sco\sigma = 1$ , it can be said that 95% of the learners will be capable of learning the SCO in a time of from 9 to 13 minutes. The area the interval covers is shaded in Figure 10.

Based on these studies and our heuristic knowledge of learning objects design, it was decided that, in this phase of e-course technological design, the SCOs of the e-lessons studied by over 90 learners whose  $elt$  are not within the interval  $[mlt-2\cdot sco\sigma, mlt+2\cdot sco\sigma]$  should be listed for possible redesign by the expert. This is precisely the case of Button Bar: the content expert estimated that the learning time would be 8 minutes, but, in actual fact, it almost always takes from 9 to 13 minutes. Therefore, its content either needs to be redesigned or, failing this, a new estimated time should be analysed. The Page Invocation learning object is a similar case: the content expert estimated a learning time of 7 minutes, when it really takes from 2 to 6.

## CONCLUSION

Research and development into e-learning/teaching has focused mainly on the implementation of technological resources and the definition of standards for sharing and reusing the learning objects. Less effort has, however, gone into defining instructional and technological design processes suited for this type of teaching, leaving their ad hoc design to the instructor. This has led us to define an instructional learning design method as a guide for content expert, master instructor and instructors to create learning objects, learning objectives and the learner's self-paced learning process and a technological design method to create an e-course that matches the learner's needs and which can also evaluate the design of the learning objects by the content expert in terms of e-content learning efficiency.

The instructional learning design method sets out the instructional design of learning objects content based on facts, concepts, processes, procedures and principles, which are educational elements that define the educational contents, tasks, solved exercises and evaluation exercises of an e-lesson. An e-course is structured as a set of e-lessons, which are educational objectives implemented by means of learning objects and deployed in a learning management system (LMS).

For the purpose of evaluating the content design of the learning objects, four fields have been added to each object: the time estimated by the content expert that it takes to learn the learning object, the number of learners who have learned it, the mean time it takes to learn it, and the standard deviation with respect to the mean time. These statistics are used to evaluate whether the content expert's design of a learning object matches his or her learning time

expectations with respect to the time taken by learners. This value is very important as e-course scheduling is based on the time defined for each learning object. Additionally, a learner's learning ability may be being inadequately evaluated owing to a poor design or poor estimation of the learning objects learning time.

The learning technology design method is very simple and instinctive. It is summarised as: what is to be taught? (E-Course Objective Definition), to whom are these educational contents to be taught? (Learner Objectives Definition) and how are these educational contents to be taught to the learner? (Learner Learning Route Definition). The system outputs the self-paced learning process, which includes a learning tree containing the structure and contents of each e-lesson, and automatically reviews this process by analysing the results of learner performance.

The proposed technology method is conceived as an open system. Therefore, its implementation in the Adaptive Learning System is easy to integrate. There are two advantages to this: firstly, the generated e-courses can be implemented in any learning management system; secondly, existing learning sources can be reused. These two benefits contribute to expanding the amount of available web learning material, enriching learning experiences.

This instructional and technological model is now being implemented to train Spanish central and local administration computing specialists [19]. The Master in Information and Communications Technologies Management [23] has been taught for over 10 years, first through classroom learning, which was later combined with live e-learning and has now been enhanced with self-paced learning.

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